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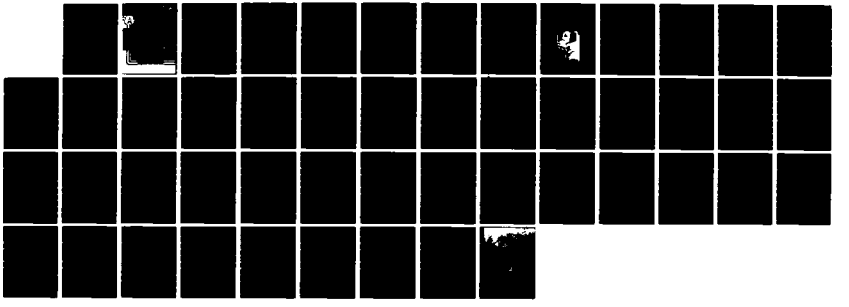

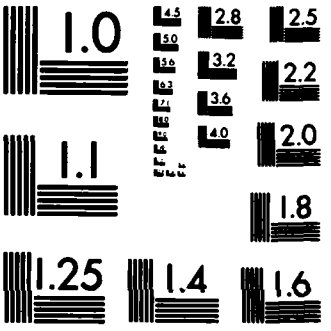

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HELICOPTER IN-FLIGHT MONITORING SYSTEM SECOND GENERATION (HIMS II)

By
Heber D. Jones
J. Alan Lewis
Alford A. Higdon, Jr.

RESEARCH SYSTEMS DIVISION

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August 1983

U.S. ARMY AEROMEDICAL RESEARCH LABORATORY
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Presented is a description of a computerized airborne data acquisition system used to measure pilot performance in a UH-1 helicopter. The unit can record approximately 20 aircraft parameters in addition to other experimental data. This report can also serve as an operator's manual for the system.

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INTRODUCTION

In order to measure the factors which affect the performance of rotary-wing aviators, the United States Army Aeromedical Research Laboratory (USAARL) instrumented a JUH-1H helicopter to monitor aircraft position, motion, and other performance measures. The Helicopter In-Flight Monitoring System--second generation (HIMS-II) is an update of the original device reported in USAARL Report No. 72-11 (March 1972), incorporating computer technology.

Figure 1 shows the HIMS-II mounted behind the copilot's seat in the JUH-1H. This system can provide continuous sampling and display up to 64 measurements, such as aircraft performance, position in space, position

FIGURE 1. HIMS-II as installed behind the copilot's seat in the JUH-1H.

of pilot controls, g loading, angular rates, and test related data. A discussion of the various aircraft sensors and signal sources is presented in Appendix A. Each parameter can be sampled at various rates to 20 samples per second. The analog-to-digital (A/D) converter channel selection, sampling rate selection, display selection, and calibration information can be customized to a specific user's requirements, saved on tape, and recalled for each data acquisition session.

This report will familiarize the reader with various aspects of the HIMS-II and also may be used as an operator's manual.

HARDWARE CONFIGURATION

The major components of the system are shown in Figure 2. The filter chassis contains the signal conditioning circuits which convert the aircraft signals into voltages usable by the computer. Converting these analog signals

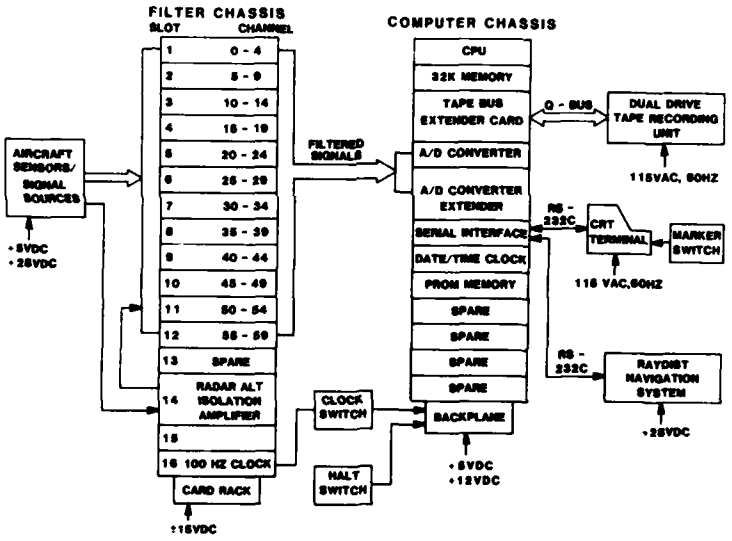

FIGURE 2. Block diagram of the HIMS-II airborne data acquisition system.

into digital words for storage, controlling the tape recorder, and interfacing with the Raydist navigation system and the operator are the functions carried out by the elements of the computer chassis. Also shown in the diagram are the dual drive tape recording unit which stores the data processed by the computer, the CRT terminal used to enter commands and display data, and the Raydist navigation system which is used to determine position within the Raydist range area.

All power for the system is derived from the aircraft 28VDC source, whether used directly, through DC-to-DC converters, or after converting to 115 VAC, 60 Hz through the use of an inverter.

The functions of the elements of the filter and computer chassis are as follows:

A. Filter Chassis

Analog Filters	--Provide conditioning of sensor signals to include antialias filtering (5 Hz cutoff frequency), buffering, attenuation, and offset so as to provide output signals between 0 and 5 volts, the allowable range for the A/D system. (See Analog Filters, next page.)
Isolation amp	--Provides isolation for the radar altimeter differential output signal.
100 Hz Clock card	--Provides a crystal-controlled clock signal which is routed to the central processing unit (CPU) external event line and used to precisely time the data acquisition cycle.

B. Computer Chassis

CPU (DEC LSI-11/2)	--Executes instructions contained in the memory.
32K memory (DEC MSV11-DD)	--Contains program instructions and data.
Tape Bus Extender card (DEC M9401)	--Provides the means for the CPU to read and write on both tape drives. The tape interface is located in the base of the tape unit.
A/D Converter and Extender cards (ADAC 1012/1012-EX)	--Provide the means for the CPU to obtain a digital representation of the voltage on each of the 64 analog input lines. (See Analog-To-Digital Converter, next page.)
Serial Interface card (DEC DLV11-J)	--Provides communication between the CPU and four devices utilizing the RS-232 data interface. Two of these channels are in use; one communicates with the Hazeltine CRT terminal and the other with the Raydist navigation system.
Date/Time card (Digital Pathways TCU-50)	--Provides date and time of day to the CPU from a battery operated clock.

PROM Memory card (DEC MRV11-BA)	--Provides up to 4K-word PROM (2708 chip) and 256 word RAM locations. A 1K-word PROM at address 170000 holds the bootstrap for the tape unit.

ANALOG FILTERS

The analog filter system in the left chassis of the HIMS-II mainframe serves two important functions for each of the 64 possible input channels. (Refer to Appendix B for the channel assignments.)

First, the sensor voltage is passed through an amplifier which provides buffering and potentiometer adjustment for attenuation and offset. These adjustments are made precisely using USAARL analog computer and the hybrid computer program CALFILTR. These adjustments, when properly made, enable the HIMS-II to process sensor voltages between -15 volts and +15 volts using the 0 to +5 volt A/D system without clipping and without loss of resolution. Appendix C outlines the procedure for calibration of the analog filter cards (not to be confused with calibration of an A/D channel). Appendix D contains a sample printout summarizing the calibration of sensors and filter cards.

Second, the sensor voltage is passed through a 4-pole, low-pass filter with a fixed cutoff frequency of approximately 5 Hz. This filtering insures that the digitized data will not be aliased due to harmonics of the sampling frequency present in the data, providing the sample rate is 10 or 20 Hz. If sampling rates lower than 10 Hz are used, the possibility of aliasing is present. Judgments of the advisability of lower sampling rates only can be made if the frequency content of the data channel is known.

ANALOG-TO-DIGITAL CONVERTER

The analog data system of the HIMS-II computer consists of a model 1012 analog-to-digital converter and a model 1012EX multiplexer expander, both manufactured by the ADAC Corporation. The hardware converts analog voltages in the range of 0 to +10 volts to 12 bit precision using the successive-approximation technique in approximately 10 microseconds. Each data sample stored by the program consists of 6 bits which identify the channel number (0-63) and the middle 10 bits from the analog-to-digital converter. The resulting 16-bit word can be rapidly and efficiently manipulated by the computer for storage and display. The system, therefore, can record and store up to 64 channels whose voltages vary between 0 and +5 volts to a precision of 10 bits (about .1% resolution).

TAPE RECORDING SYSTEM

Data and programs are stored using a Qantex Model 2200 data cartridge storage system. The system contains a formatter, an LSI-11 interface, and two tape drives which use the 3M data cartridge (DC 300A) as the storage medium. Data is recorded serially on four tracks at a density of 1600 bits per inch and at a speed of 30 inches per second for a transfer rate of 3000 words per second. During a data acquisition session, storage begins on track 1 of drive 0 with an 800-word header record and continues with 512 data records of 504 words each, using about 85% of a 300-foot cartridge. (The format of these records is given in Appendix E.) Drive 0 then is rewound at 90 inches per second as the data recording is switched over to track 1 of drive 1. This rewind-and-switch procedure is continued until track 4 of drive 1 is started. The cartridge in drive 0 then is ejected by the program and the operator must place a new cartridge in the tape drive before the next switch occurs. The time remaining until the switchover to the other drive is displayed on the terminal screen along with other data when the operator executes command #2, 3, or 5 (display data). New cartridges can be inserted as required for truly unlimited, continuous data acquisition.

RAYDIST NAVIGATION SYSTEM

The Raydist RA-89 airborne receiver processes signals from ground-based stations which are located at the corners of the 100-square-mile Highfalls test area. This receiver converts the signals into precision position information in the form of audio frequency signals. The GA-62 position indicator compares the phase of the audio signals from the receiver and provides a visual readout of position in Raydist "lane" counts. The position indicator is equipped with a 9600 baud RS-232-C computer interface which transmits the lane counts to the HIMS-II computer at a speed sufficient to provide sampling of position at the same rates as for analog data channels (.5, 1, 2, 4, 5, 10, and 20 Hz).

Utilizing the Raydist lane counts, the HIMS-II software computes absolute ground position in coordinates which are identical to those of military maps of the Highfalls area. The navigation system requires absolute continuity in the operation of the four base station transmitters, the RA-89 receiver, and the GA-62 position indicator. (Operation of the HIMS-II computer need not be continuous.) Any disruption to the operation of any one of these units will cause an error which will remain with the system and can even grow larger. Since there are many sources of such disruption (radio static, power line interference, poor signal strength, etc.), the accuracy of the system can be greatly improved by reinitializing the system periodically at known positions on the ground.

Each ground position in the Highfalls area can be located by a unique pair of red-green lane coordinates, as read on the Raydist GA-62 position

indicator. Initialization is simply the process of presetting the lane coordinates of a known ground position into the GA-62 display. For example, the first initialization should be done at the end of the runway at Highfalls. (The location is marked by an "X.") This spot is the starting point for the Raydist lane counting system and has been assigned a value of 200,000 for each of its two lane coordinates. The procedure for initializing the Raydist is given in Appendix F.

SOFTWARE DESIGN

DATA ACQUISITION

The HIMS-II data acquisition program is an interactive, command-oriented system with concurrently operating background and foreground processes. Background functions are processed on a time-available basis and include operations such as response to operator commands and display of current measurements and derived data values. The control flow of the program is shown in Figure 3.

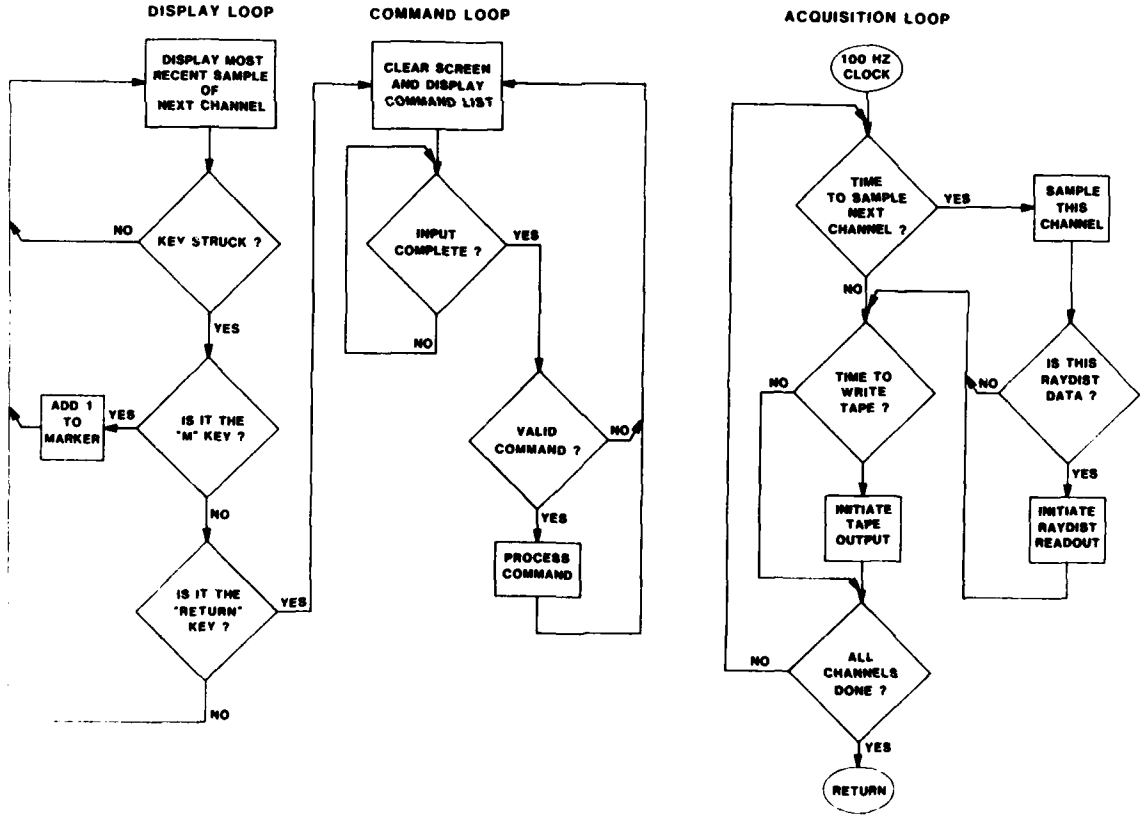

FIGURE 3. Simplified data acquisition software flowchart.

The entire foreground system is driven through a crystal-controlled clock which interrupts the background process 100 times per second. After the interrupt is serviced, the background process is resumed at the point at which it was interrupted.

The acquisition loop services every fifth interrupt for a minimum sample period of 50 milliseconds or a maximum rate of 20 Hz. By limiting the rate to 20 Hz, the operator can select channels and sampling rates without worrying about exceeding the design capabilities of the hardware. If the number of channels is limited, however, sampling rates up to 100 Hz can be accommodated.

For each clock interrupt which is serviced in the acquisition loop, a counter is advanced for each channel which is selected for data acquisition. When one of these counters reaches the sample period specified for that channel, then the first decision block produces a "yes" answer and that channel is sampled and its counter reset. The sampling process involves either an analog-to-digital conversion or capture of a value being held in memory (as in the case of Raydist data and the marker channel). If a Raydist channel was addressed, then an interrupt-driven cycle to read the Raydist information is initiated. This cycle proceeds concurrently with the acquisition loop and is completed after approximately 15 milliseconds. As samples are acquired, they are tagged with the channel number and placed into one of two tape buffers. The next decision block in the acquisition loop provides a "yes" answer when the current tape buffer is filled. Tape output then is initiated from that buffer while subsequent data is placed in the other buffer. The tape output operation also is interrupt-driven and proceeds concurrently with other processes. The time required to complete a normal output buffer transfer is approximately .25 seconds. The tape interrupt service includes, at the appropriate time, track and drive changes and ejection of full tape cartridges.

The process of loading the HIMS-II software into the computer is called bootstrapping. The software, which is stored on a tape cartridge, is loaded into memory by execution of a small program stored in read-only (permanent) memory. The procedure is given in Appendix G. Once the HIMS-II program is running, the operator has control over the various modes of the program--whether displaying data, recording data, performing calibrations, etc. These operator commands are listed in detail in Appendix H.

DATA REDUCTION

The data reduction of HIMS-II data cartridges involves a group of programs which are used to scan the data tapes, derive statistics, and examine the results. A block diagram of the programs is shown in Figure 4. The HIMS-II data reduction programs are designed to run on a disk-supported PDP-11/03 using the RT-11 operating system. Given below is a brief discussion of the major programs used in the HIMS-II data reduction.

The scanning routine (SCAN) operates on raw data tapes and gives the researcher the means to verify raw data and to identify certain events. The

retrieval of raw data from the Qantex 2200 data cartridge system is accomplished by a group of assembly language (MACRO-11) programs. During the scanning process, raw data is displayed on the CRT. A means is provided to send selected raw data channels over a high speed interface to the Systems Engineering Labs (SEL) computer for further graphical analysis.

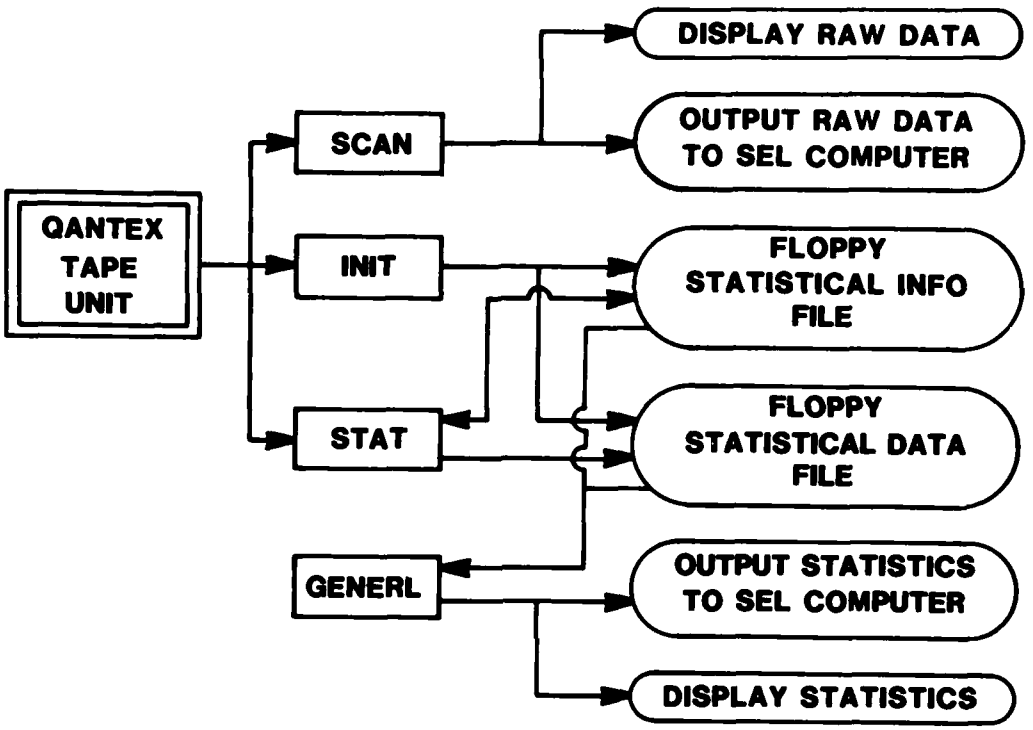

FIGURE 4. Primary data reduction software run on the laboratory-based PDP-11 computer system.

The initialization routine (INIT) lets the researcher set up the statistics to be derived for an experiment. The setup includes channel and functions, i.e., minimum, maximum, mean, standard deviation, average constant error, RMS constant error, filter, outlier, crossover, differential, time, etc. Also, factors which are unique identifiers for a specific data segment are identified by the researcher. This information is stored on associated disk files and needs only be entered once.

The statistics routine (STAT) takes a setup produced by INIT and does the statistical analysis, starting at a specified point (time, record, marker) and going to a specified end point. After analysis, each segment is stored sequentially on disk if that option is chosen.

The general purpose routine (GENERL) allows the researcher to examine a statistical segment previously generated on a disk file. The researcher can output these segments to the SEL computer to be used by the FACPLOT program for graphical analysis.

INSTALLATON AND CALIBRATION

Shown in Figure 1 is the HIMS-II unit installed in the JUH-1H aircraft. Its location allows the operator to observe the pilot while monitoring the HIMS and Raydist systems. Refer to Appendix I for the installation procedure.

The procedure for calibrating the aircraft sensors and the HIMS-II electronics is presented in Appendix J.

ERROR EVALUATION OF HIMS-II DATA

Several factors affect the amount of error in the raw data as presented by the HIMS-II unit. These include not only the accuracy of the transducer and the stability of the HIMS-II signal conditioning, but also the errors obtained when trying to relate two different transducers--the HIMS-II sensor and the pilot's indicator--each with their own linearity and hysteresis errors.

Several functions monitored by the HIMS-II have no corresponding pilot indicators. These are the control positions, angular rates, and accelerations (flight loadings). The control positions are detected by linear displacement transducers which have operating accuracies of approximately 1.0% full scale. The linearity of their output versus control movement may be less than ideal due to the method of installation. However, during normal flight conditions the controls are moved only in a small subset of the total travel, and this mounting nonlinearity will have minimal effect. The angular rate and linear acceleration transducers have errors in the range of approximately ± 2%.

Four other functions--low-range airspeed (LORAS) velocity vector, LORAS longitudinal airspeed, LORAS latitudinal airspeed, and the radar altitude--provide a signal to the HIMS-II which is similar to that driving the pilot's indicator. Since the HIMS-II is calibrated to match the indicator at two points, the only differences between recorded and indicated values would result from reading errors such as parallax or minute nonlinearities (unknown) in the system's output. Of course, aircraft system malfunctions will show up in any data that is displayed or recorded.

In a third group of functions (which include heading, pitch, roll, rotor rpm, barometric altitude, barometric airspeed, vertical airspeed, and slip), each channel uses a different sensor to provide a voltage recorded by the HIMS-II. Here the difference between the recorded and pilot-indicated values results from errors inherent in both sensors, since one is being compared to the other, and not both to a known standard.

The pitch, roll, and heading synchro signals are processed through an intermediate conversion module which has small errors of several minutes of angle.

The rotor rpm was calibrated to match the pilot's indicator at 0 and 325 rpm. The aircraft system typically has an error of 0.8% plus reading error caused by markings at only every 20 rpm--plus the fact that two needles overlap on the indicator. The HIMS-II frequency converter has a maximum nonlinearity of 0.2 rpm; therefore, the worst-case difference should be approximately 2.6 rpm at the input to the HIMS-II.

The barometric altitude and barometric airspeed calibrations--using the pilot's indicators as the standard--produced a maximum error of 70 feet and 1.2 knots again as measured at the input to the HIMS-II.

The vertical airspeed function, as calibrated under relatively controlled conditions (installed on HIMS-II rack, aircraft in hangar), produced maximum recorded errors of less than 100 feet per minute (fpm) from the indicated value. The unit's rated accuracy is ± 50 fpm for static conditions.

The slip transducer, mounted on the HIMS-II, was calibrated in flight at the one-ball left and one-ball right conditions. Due to the instability of the pilot indicator and internal nonlinearities, an empirical guesstimate of error is ± ¼ ball.

The signal conditioning circuitry (filter cards) and the analog-to-digital converter in the HIMS-II also contribute to error in the recorded data. The A-to-D converter specifications based on manufacturer's data give the following errors:

Resolution: 10 bits or $\approx$ 0.12% FS
Linearity: ± 0.025%
Stability: ± 0.039% for 30°F-100°F

Except for resolution, these errors are insignificant when compared to other system errors.

The signal conditioning circuitry was developed in-house and only empirical data exists on stability. This data, presented in Table 1, was obtained by inserting constant voltages into the HIMS-II signal conditioning channels over a period of several weeks. Also shown is the effect of a 20°F rise in ambient temperature on the displayed (and recorded) value. The root-sum-square (RSS) total is given in the last column. These errors are related only to the electronics of the present signal conditioner and do not include those in the sensors. Though each channel is distinct in its variability and temperature stability, an approximate average value of 1.5% of full scale could be used as a bound for error in the signal conditioner.

TABLE 1

HIMS-II SIGNAL CONDITIONING ERRORS

CH	LABEL	ENG. UNITS (EU)	LONG-TERM VARIABILITY (EU)	20°F TEMPERATURE RISE EFFECT (EU)	RSS TOTAL (EU)
0	RPM	rpm	0.5	0.4	0.6
1	BALT	ft	27	42	50
2	A/S-V	KT[1]	1.1	0.6	1.3
3	CYCFA	%	1.0	4.2	4.3
4	CYCLR	%	0.5	2.4	2.5
5	COLL	%	0.8	3.5	3.6
6	THROT	%	0.4	0.7	0.8
7	PEDAL	%	2.0	1.7	2.6
8	LORA VEL	KT	0.13	0.4	0.4
9	LORA LON	KT	0.19	2.4	2.4
10	LORA LAT	KT	0.46	0.2	0.5
11	RALT	ft	3.9	6.4	7.5
18	ROL RATE	°/sec	1.2	0.2	1.2
19	PIT RATE	°/sec	1.0	0.2	1.0
20	YAW RATE	°/sec	1.1	3.0	3.2
21	X ACCEL	g	0.04	0.01	0.04
22	Y ACCEL	g	0.16	0.01	0.16
23	Z ACCEL	g	0.04	0.05	0.06
24	VERT A/S	fpm	23	58	62
25	SLIP	ball	.04	0.2	0.2

[1] Channel 2 measures volts; however, the errors shown are in equivalent knots (at 80 KIAS).

LIMITATIONS IN DATA ACQUISITION

The error specifications given for a sensor or recording system only apply if the unit is operating within its designed or calibrated ranges. Likewise, the HIMS will record accurately only if it is operated within certain ranges. The method of calibration also will affect the range where the HIMS-II data is most accurate. Some channels are calibrated by using the test feature provided on the pilot's indicator and the values provided may cover only a small portion of the entire range of the indicator. Other channels are calibrated over the entire range of operation.

The following is a brief discussion on the limits of each type of sensor and its data channel. Awareness of these will assist the researcher/operator in the planning and data gathering phases of a research project.

Rotor RPM	--Set to measure 0 to 357 RPM.
Baro Altitude	--Currently set to measure -200 to +2600 feet MSL with 29.92 set in pilot's altimeter. (Other altimeter settings will vary these extremes.) The sensor will operate to altitudes above 10,000 feet.
Baro Airspeed	--Set to measure from 30 knots indicated airspeed (KIAS) to approximately 120 KIAS. The sensor can measure from 30 to 210 KIAS.
Control Positions	--Due to the method used to mount the transducers, some nonlinearity and variability will occur. These channels will measure the entire range of control movement.
LORAS	--These channels are calibrated to match the indicators on the console using the test feature. These test values are approximately 0 and 9 KIAS for the lateral signal and 0 and 50 KIAS for the longitudinal signal. Neither have any relation to the value provided by the barometric airspeed channel. Maximum readings are -30 to +30 KIAS for lateral and -20 to +120 KIAS for longitudinal airspeed.
Radar Altitude	--The calibration, using the test feature, is made at the values of 0 and 110 feet. The best agreement in data recorded versus that indicated will be at these lower altitudes. Maximum reading is set for 1500 feet, the limit of the altimeter.
Vertical Airspeed	--Set for the range of 0 ± 2000 feet per minute. The sensor for this channel responds much more quickly than the pilot's indicator causing some disagreement during transitional periods.

Slip	--Calibrated for ± 1 ball deflection. The in-flight calibration is somewhat inaccurate due to an unstable reference.
Heading, Pitch, and Roll	--All three will read 360° of rotation even though pitch and roll only use a small portion of the range. The pilot's attitude indicator has a mechanical offset control for pitch which will change the relationship of the pilot's indication to the HIMS data.
Roll, Pitch, and Yaw Rates	--These are set to read ± 100°/second, maximum.
X, Y, and Z Accelerations	--The X and Y channels will read approximately ± 2.5 g, while the Z axis reads ± 5 g, maximum.

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Appendix A

AIRCRAFT SENSORS

There are a variety of sensors and signal converters which provide voltage signals to the HIMS-II for display and recording. The following is a brief discussion of these units.

Channel 0: Rotor rpm

A frequency-to-DC converter, mounted in the JUH-1H aircraft nose compartment, converts the rotor tach-generator signal to a calibrated DC voltage between 0 and 5 volts.

Channel 1: Barometric altitude

This pressure transducer, connected to the aircraft static pressure line, converts the absolute barometric pressure to movement of a potentiometer wiper arm. The 5000-ohm potentiometer is excited by a regulated +5V DC from the HIMS-II chassis. The output voltage from the wiper is related to altitude and is calibrated to match the pilot's altimeter with 29.92 set in the Kollsman window. The unit measures altitudes up to 10,000 feet.

Channel 2: Barometric airspeed

Similar to the barometric altimeter transducer, the airspeed transducer is connected to ship's static and pitot pressure lines, and measures impact pressure. It is a potentiometer device with its output voltage calibrated against the pilot's airspeed indicator. Conversion to indicated airspeed (from impact pressure) is done by the computer. Along with the altitude transducer, it is mounted in the nose compartment.

Channels 3-7: Control position measurements

The cyclic fore-aft, cyclic left-right, collective, throttle, and pedal positions are each measured with string-type potentiometer position transducers. These 5000-ohm units are mounted to the linkage of each control below the aircraft floorboards. Also excited by the +5V DC supply from the HIMS-II chassis, their outputs are between 0 and 5 volts and related to the control position.

Channels 8-10: Low-range airspeed (LORAS)

These three signals--velocity vector, longitude, and lateral airspeeds--are obtained from the LORAS system. The velocity vector and longitude component are DC voltages with a scale factor of 20 knots/volt. The lateral component is specified as 5 knots/volt.

Channel 11: Radar Altitude

Generated by the R/T unit of the radar altimeter system, this DC voltage is calibrated at -4mv/foot. The differential output of this unit is conditioned to a single-ended signal by an amplifier in the HIMS-II filter chassis. The signal is valid from 0 to 1500 feet above ground level (AGL) and matches the pilot's indication.

Channels 12-17: Sine/cosine for roll, heading, and pitch

The synchro and reference signals from the aircraft vertical gyro are converted by two synchro-to-sin/cos converter modules to provide sine and cosine signals for roll and pitch. The aircraft directional gyro synchro signals are converted to provide the sine and cosine signals representing heading. The module outputs vary between -10 and +10 volts.

Channels 18-20: Roll, pitch, and yaw rates

These signals are obtained from three rate gyros mounted on the HIMS-II rack. The output signals come from the wipers of three 5000-ohm potentiometers which are excited by the 5 volt supply and are calibrated from 0 to 100 degrees/second.

Channels 21-23: X, Y, and Z accelerations

Aligned with the aircraft X, Y and Z axes, these accelerometers measure static g forces. They are potentiometric units excited by 5 volts and are located on the HIMS-II rack. The vertical accelerometer measures up to 5 gs; the other accelerometers measure to 2 gs.

Channel 24: Vertical airspeed

Also mounted on the HIMS-II rack, this transducer senses a change in the static pressure and produces an output very similar to the pilot's VVI indication. The output signal has a nominal value of 2.0 V per 1000 feet per minute.

Channel 25: Slip

This signal is created by a modified turn and slip indicator mounted on the HIMS-II rack. The output voltage is related to the deflection of the ball in the indicator.

Appendix B

STANDARD CHANNEL ASSIGNMENTS

CHANNEL NUMBER	UNITS OF MEASURE	NOMINAL RANGE	MEASUREMENT
0	RPM	0 to 360	Rotor Rate
1	Feet	0 to 10,000	Barometric Altitude
2	Volts	0 to 5	Airspeed Sensor Voltage (See #64)
3	%	-100 to 100	Cyclic Fore-Aft
4	%	-100 to 100	Cyclic Left-Right
5	%	0 to 100	Collective
6	%	0 to 100	Throttle
7	%	-100 to 100	Pedal
8	Knots	0 to 120	LORAS Airspeed (Resultant)
9	Knots	-20 to 120	LORAS Airspeed (Fore-Aft)
10	Knots	-30 to 30	LORAS Airspeed (Left-Right)
11	Feet	0 to 1500	Radar Altitude
12	Pure#	-1 to 1	Sine of Roll Angle
13	Pure#	-1 to 1	Cosine of Roll Angle
14	Pure#	-1 to 1	Cosine of Heading Angle
15	Pure#	-1 to 1	Sine of Heading Angle
16	Pure#	-1 to 1	Cosine of Pitch Angle
17	Pure#	-1 to 1	Sine of Pitch Angle
18	Deg/Sec	-100 to 100	Roll Rate
19	Deg/Sec	-100 to 100	Pitch Rate
20	Deg/Sec	-100 to 100	Yaw rate
21	G	-2 to 2	X Acceleration (Fore-Aft)
22	G	-2 to 2	Y Acceleration (Left-Right)
23	G	-5 to 5	Z Acceleration (Up-Down)
24	Ft/Min	-2000 to 2000	Vertical Airspeed
25	BALL	-1.00 to 1.00	Slip (BALL)
26	-	-	General Purpose BNC Connector #26
27	-	-	" " " " #27
28	-	-	" " " " #28
29	-	-	" " " " #29
30	-	-	" " " " #30
31	-	-	" " " " #31
32	-	-	" " " " #32
33	-	-	" " " " #33
34	-	-	" " " " #34
35	-	-	" " " " #35
36	-	-	" " " " #36
37	-	-	" " " " #37
38	-	-	" " " " #38
39	-	-	" " " " #39
40	-	-	" " " " #40
41	-	-	" " " " #41
42	-	-	" " " " #42

CHANNEL NUMBER	UNITS OF MEASURE	NOMINAL RANGE	MEASUREMENT
43	-	-	General Purpose BNC Connector #43
44	-	-	General Purpose BNC Connector #44
45	-	-	" " " " #45
46	-	-	" " " " #46
47	-	-	" " " " #47
48	-	-	" " " " #48
49	-	-	" " " " #49
50	-	-	" " " " #50
51	-	-	" " " " #51
52	-	-	" " " " #52
53	-	-	" " " " #53
54	-	-	" " " " #54
55	-	-	" " " " #55
56	Clocks	0 to 1023	Scan Counter
57	Pure#	1 to 1023	Marker Counter
58	Pure#	0 to 1023	Trap Counter (Vector 360)
59	Pure#	0 to 1023	Tape Error Counter
60	Counts	0 to 1023	HI Order Raydist Red Lane Count
61	Counts	0 to 1023	LO Order Raydist Red Lane Count
62	Counts	0 to 1023	HI Order Raydist Green Lane Count
63	Counts	0 to 1023	LO Order Raydist Green Lane Count
64	Knots	0 to 120	Indicated Airspeed (Calculated)
65	Deg	0 to 360	Heading Angle (Calculated)
66	Deg	-180 to 180	Pitch Angle (Calculated)
67	Deg	-180 to 180	Roll Angle (Calculated)
68	KM	9 to 26	East-West Map Coordinate (X)
69	KM	36 to 51	North-South Map Coordinate (Y)

Appendix C

FILTER CARD CALIBRATION PROCEDURE

1. Mount patch panel #2 (labeled "HIMS-II CAL") on the analog computer. Connect the inputs and outputs of the filter card test module to the appropriately labeled BNC connectors on the patch panel. Refer to analog schematic drawing #2 (in the computer room) if necessary.

2. Activate program CALFILTR.

3. Respond to the questions asked by the program. The features which are available are:

a. Adjust attenuation and offset of any of the five channels on the card. You specify the two calibration voltages. All adjustments to the card are prompted by the program.

b. Measure input and output voltages for N steps (you specify N) from the lower calibration voltage to the higher calibration voltage. Determine the best calibration constants (slopes and normals) by the method of least squares.

c. Graph all measurements so as to show deviation from linearity, noise level, breakdown points (if any), and low frequency drift.

Appendix D

SAMPLE HIMS-II STANDARD CALIBRATION SHEET

The latest edition of the HIMS-II standard calibration sheet can be obtained from the line printer in the computer center by activating program HIMS2CAL from any terminal. See computer listing on next page.

••• HIMS-II STANDARD CALIBRATION DATA •••

CHANNEL #	SLOT #	SUB #	NAME	SENSOR CALIBRATION STD#1 (VOLTS)	SENSOR CALIBRATION STD#2 (VOLTS)	SENSOR CALIBRATION STD#1 (ENG UNITS)	SENSOR CALIBRATION STD#2 (ENG UNITS)	FILTER OUTPUT #1	FILTER OUTPUT #2	SENSOR VOLTS SLOPE	SENSOR VOLTS NORMAL	HIMS-II A/D SLOPE	HIMS-II A/D NORMAL
0	1	1	RPM	0.000	5.000	0.000	357.500	0.204	4.801	0.0053155	-0.22181	0.3796858	-15.8591
1	1	2	BALT	0.000	1.000	-1000.000	3000.000	0.199	1.081	0.0055437	-0.22570	22.1530647	-1902.8071
2	1	3	A/S-V	1.932	7.676	30.000	120.000	1.991	7.309	0.0052791	-0.21852	0.0826347	-3.6954
3	1	4	CYCFA	1.340	4.810	100.000	-100.000	1.482	4.660	0.0052740	-0.21894	-0.3072223	193.2328
4	1	5	CYCLR	0.120	2.210	100.000	-100.000	0.321	2.170	0.0055259	-0.24301	-0.5282759	134.7378
5	2	1	COLL	2.800	4.170	0.000	100.000	2.697	3.914	0.0055016	-0.23537	0.4611814	-221.5596
6	2	2	THROT	3.680	4.920	0.000	100.000	3.319	4.366	0.0057877	-0.24986	0.4662931	-316.9240
7	2	3	PEDAL	0.980	3.490	-100.000	100.000	1.031	3.166	0.0057459	-0.23201	0.4573943	-196.5743
8	2	4	LORA VEL	0.000	5.950	0.000	120.000	0.200	3.243	0.0095580	-0.39156	0.1925784	-7.8971
9	2	5	LORA LON	0.000	5.950	0.000	120.000	0.210	4.770	0.0063776	-0.27358	0.1284978	-5.5175
10	3	1	LORA LAT	-5.888	5.776	-30.000	30.000	0.189	4.741	0.0125242	-6.37258	0.0643622	-32.4927
11	3	2	RALT	0.000	6.000	0.000	1500.000	0.219	4.821	0.0063720	-0.28573	1.5914464	-71.4336
12	3	3	SINROLL	-10.000	10.000	-1.000	1.000	0.233	4.827	0.0212772	-11.01476	0.0021256	-1.1015
13	3	4	COSROLL	-10.000	10.000	-1.000	1.000	0.228	4.898	0.0209318	-10.97730	0.0020911	-1.0977
14	3	5	COSHEAD	-10.000	10.000	1.000	-1.000	0.180	4.811	0.0211081	-10.77780	-0.0021088	1.0778
15	4	1	SINHEAD	-10.000	10.000	1.000	-1.000	0.211	4.794	0.0213292	-10.92036	-0.0021308	1.0920
16	4	2	COS PIT	-10.000	10.000	-1.000	1.000	0.211	4.843	0.0211017	-10.90925	0.0021081	-1.0909
17	4	3	SIN PIT	-10.000	10.000	-1.000	1.000	0.222	4.788	0.0214114	-10.97315	0.0021391	-1.0973
18	4	4	ROL RATE	2.520	4.995	0.000	100.000	2.409	4.564	0.0056122	-0.24568	0.2265330	-111.7446
19	4	5	PIT RATE	2.515	5.000	0.000	100.000	2.399	4.546	0.0056560	-0.26130	0.2273839	-111.7224
20	5	1	YAW RATE	2.500	5.000	0.000	100.000	2.291	4.383	0.0058399	-0.23696	0.2333678	-109.4785
21	5	2	X ACCEL	1.592	3.429	-2.000	2.000	1.640	3.287	0.0054487	-0.23589	0.0118527	-5.9802
22	5	3	Y ACCEL	1.578	3.412	-2.000	2.000	1.628	3.283	0.0054151	-0.22574	0.0117989	-5.9346
23	5	4	Z ACCEL	0.214	4.807	-5.000	5.000	0.389	4.437	0.0055469	-0.22799	0.0120650	-5.9623
24	5	5	VERT A/S	-0.495	3.505	0.000	2000.000	2.483	4.560	0.0094119	-5.27633	4.7013407	-2390.6670
25	6	1	SLIP	1.056	-2.719	-1.000	1.000	3.488	0.000	0.0052907	-2.71909	-0.0028000*	1.0000*
26	6	2	BNC #1	0.000	5.000	-100.000	100.000	0.208	4.786	0.0053378	-0.22736	0.2133024	-109.0942
27	6	3	BNC #2	0.000	5.000	-100.000	100.000	0.244	4.734	0.0054424	-0.27181	0.2174851	-110.8724
28	6	4	BNC #3	0.000	5.000	-100.000	100.000	0.208	4.795	0.0053278	-0.22679	0.2129025	-109.0715
29	6	5	BNC #4	0.000	5.000	-100.000	100.000	0.210	4.793	0.0053321	-0.22933	0.2130744	-109.1731
30	7	1	BNC #5	0.000	5.000	-100.000	100.000	0.203	4.809	0.0053054	-0.22014	0.2120081	-108.8054
31	7	2	BNC #6	0.000	5.000	-100.000	100.000	0.199	4.800	0.0053118	-0.21606	0.2122639	-108.6426
57			PARK	N/A	N/A	N/A	N/A						
58			#BADVEC	N/A	N/A	N/A	N/A						
59			#TAPERR	N/A	N/A	N/A	N/A						
60			X1 RAY	N/A	N/A	N/A	N/A						
61			X2 RAY	N/A	N/A	N/A	N/A						
62			Y1 RAY	N/A	N/A	N/A	N/A						
63			Y2 RAY	N/A	N/A	N/A	N/A						
64			AIRSPEED	N/A	N/A	N/A	N/A						
65			HEADING	N/A	N/A	N/A	N/A						
66			PITCH	N/A	N/A	N/A	N/A						
67			ROLL	N/A	N/A	N/A	N/A						
68			X(MAP)	N/A	N/A	N/A	N/A						
69			Y(MAP)	N/A	N/A	N/A	N/A						

* DETERMINED FROM FIELD CALIBRATION

Appendix E

TAPE DATA FORMAT

HEADER RECORD: 800 Words

WORD #	Description
1	Release Number
2 - 3	ASCII String "Head"
4	Number of Characters in Header
5 - 40	User-Supplied Head (Up to 72 Characters)
41 - 552	64-Entry Array as Follows: Channel Name - 4 Words (8 Characters) Real Slope - 2 Words Real Normal - 2 Words
553 - 584	64-Entry Byte Array (Contains Channel Sample Period; a Zero Means the Channel is not Selected for Sampling)
585	Number of Channels Selected for Display
586 - 617	64-Entry Byte Array (Contains Channel Display Flag)
618	Channel Pointer to "Recent"
619 - 682	64-Entry Array Containing Most Recent Channel Data
683	Maximum Number of Channels (64)
684	Scratch
685	Maximum Sample Period (40)
686	Number of Bytes of Data Per Tape Record (1000)
687	Number of Tape Data Records Per Track (512)
688	Initial Tape Drive (1)
689	Initial Tape Track (1)
690 - 708	Scratch
709	Starting Month, Day (1 Byte Each)
710	Starting Hour, Minutes (1 Byte Each)
711	Starting Year, Seconds (1 Byte Each)
712 - 800	Future Expansion

DATA RECORD: 504 Words

WORD #	Description
1 - 500	Tagged Channel Data (6 Bit Channel #, 10 Bits Data)
501	Current Month and Day (1 Byte Each)
502	Hours and Minutes (1 Byte Each)
503	Year and Seconds (1 Byte Each)
504	Tape Record Number

Appendix F

RAYDIST INITIALIZATION

The procedure for Raydist initialization is as follows:

1. Insure that all units in the navigation system have been on for at least 10 minutes (four base station transmitters, RA-89 receiver, and GA-62 position indicator). The GA-62 must be in "track" mode with the integration selector in position 2 for anticipated flight speeds of less than 100 knots, or position 3 for speeds greater than 100 knots (up to 160 knots). Check that the RA-89 channel selector is in the "1" position.

2. Position the aircraft precisely at or directly above the known ground position. Find the altitude which produces the most stable display on the GA-62 position indicator and hover there until initialization is complete.

3. Set the lane coordinates for the known ground position into the thumbwheels on the GA-62 position indicator. (See Table F-1 for lane counts and map coordinates for several significant terrain features.) Push the preset button.

4. Note that the last two digits of each coordinate do not preset to the thumbwheel value. The last two thumbwheel settings must be varied (push the preset button each time) until the GA-62 display exactly matches the known lane coordinates. (For the last two digits, the 2-digit thumbwheel number is a constant which the GA-62 position indicator adds to a number contained within its electronics. Any carry into the third digit is lost since the third digit is preset exactly to the thumbwheel value.) For example, after you have entered the known lane count into the thumbwheel and pressed the preset button, if:

T = Original thumbwheel number (last 2 digits)

N = Known lane count (last 2 digits)

D = Display number (last 2 digits)

X = New thumbwheel number (last 2 digits)

Then:

$$X = T + N - D \quad \text{(Use last 2 digits only)}$$

5. Initialization is complete when both the red and green displays match the known lane counts at the same time.

TABLE F-1

MAP AND RAYDIST LANE COORDINATES OF SOME PROMINENT TERRAIN FEATURES IN THE HIGHFALLS AREA

TERRAIN FEATURES		RAYDIST LANE COUNT RED	GREEN	MAP COORDINATES KILOMETERS E-W	N-S
Highfalls Runway	Origin	200000	200000	14.69	40.17
90 Deg Road Turn	CK #1	200110	199366	14.58	40.47
Road Intersection	CK #2	200376	198420	14.45	40.94
Wesley Branch Bridge	CK #3	197264	195308	12.51	41.35
Road Intersection	CK #4	202858	192508	13.85	43.90
Barnes Creek-Choc. River	CK #5	207072	191660	15.20	45.32
Barnes Creek Bridge	CK #6	207134	195566	16.25	43.88
Fellowship Church	CK #7	211086	201284	19.37	42.75
Barnes Creek Junction	CK #8	211704	202856	20.12	42.30
Road Intersection	CK #9	209030	206094	19.86	40.43
Road-Power Line	CK #10	206964	209868	19.90	38.46
Road Intersection	CK #11	206192	199678	16.96	42.09
Road Intersection	CK #12	195378	199606	12.85	38.83
Creek Intersection	CK #13	192964	194378	10.65	40.61
Road Intersection	CK #14	195836	190436	10.50	42.89
Barrow Pits	CK #15	199486	186250	10.69	45.39
Bridge	CK #16	203306	178684	9.93	49.10
Broxson Creek Junction	CK #17	207028	181752	12.55	48.99
Road Intersection	CK #18	214618	185592	16.34	50.14
Choctawhatchee River	CK #19	209292	187976	15.05	47.33

Appendix G

POWER-UP AND COMPUTER BOOTSTRAP

The process of loading the HIMS-II data acquisition program from a tape is called bootstrapping. This is accomplished by placing the program tape in the left drive and then executing the bootstrap program starting at location 170000_8. The entire data acquisition program then is transferred to memory beginning at location 500_8, an operation which takes about 10 seconds. The step-by-step procedure is as follows:

1. Position the CPU switch to "RUN ENABLE," and the clock switch to "OFF."

2. Insure proper 28V DC and 115V AC, 60 Hz power is available (check the inverter output for stability).

3. Turn on the power for the terminal, tape unit, computer, calibration box, and Raydist system (if used).

4. Allow warmup of 15 minutes.

5. Insert the program tape in the left drive; check that the busy light is off.

6. Enter through the keyboard: 170000G

If the computer halts immediately (without moving the tape) with the display:

```
170000
@
```

Then press the letter P on the keyboard (do not hit return). If it halts with any other display, then re-enter 170000G.

7. Wait about 10 seconds for the program to load. If the load was successful, the program will clear the screen and display the list of program commands while also rewinding and ejecting the tape cartridge. If the load was not successful, up to 10 retries automatically will be attempted. These reattempts may be halted at any time by pressing the "break" key.

8. Once ejected, remove the program tape and store it in a safe place.

9. Proceed with the calibration and data acquisition functions as explained in the Operator Commands, Appendix H.

Appendix H

OPERATOR COMMANDS

(The following section has been written as if the reader is the operator.) When the command list is visible on the screen, execute each of the comments by entering its number and a carriage return.

COMMAND 0. AUTO CALIBRATE

This feature allows for calibration of the HIMS-II signal conditioner, A/D converter, and computer systems by the method of voltage substitution. For each of the first 26 channels, the calibration box provides two constant voltages which have been equated to engineering units. At the beginning of a data gathering session, the computer samples these voltages and calculates slope and normal calibration constants. These values will be used for that session and will compensate for small changes in the data voltages due to temperature and long-term drift.

The following steps describe the calibration procedures:

a. Follow the instructions as prompted on the terminal. These include turning the HIMS-II clock switch on and positioning the HI/LO calibration switch on the calibration box.

b. Once both the high and low values have been read in by the computer, the terminal will display any errors. These represent changes in slope or normal beyond specified tolerances. They also can be an excessively noisy signal. Record any errors displayed (note channel number) for later diagnostic work. Critical data channels which display an error must be corrected before data gathering.

c. For each channel with an error displayed, the operator can accept the new slope and normal values by entering a Y (yes), or use the old values by entering an N (no).

d. When completed with the auto calibration, save the program on another tape (not the program master first loaded in). Use this tape for subsequent data gathering.

e. Disconnect the "A" cable from the calibration box and connect it to the aircraft console. Remove the "C" and "D" cables from the calibration box and connect the proper HIMS-II cables. This will restore the HIMS-II for normal data gathering.

COMMAND 1. HEADER

Displays the old header and allows you to change it. The header is a 72-character string which is written on the first record of a data tape

when command #3 is executed. You can use this string to specify experimental factors which can be retrieved and used by the processing program. The layout you use should be carefully planned and coordinated with computer and statistical support personnel. Above all, you should be consistent from one data acquisition session to the next.

NOTE: The proper header must be entered before data acquisition and storage to tape is begun.

COMMAND 2. START A/D ONLY

Enables data acquisition without storage to tape. Actual acquisition begins when you turn the clock switch on (begins immediately if the clock is already on). If you hit an extra return after this command, the program will execute command #5. Pressing the letter M on the keyboard (do not hit return) or activating the marker pushbutton increments the marker counter which occupies data channel #57. The program sets this counter to 1 when data acquisition is enabled with command #2 or #3. While data is being displayed as a result of command #5, you can increment the marker counter without disturbing the display.

COMMAND 3. START A/D AND TAPE

Enables data acquisition with storage to tape. The program writes the header record to tape at this time. If the program detects an error while writing the header, you will be asked what to do. The choices are, in preferred order:

a. Put in a new tape cartridge and tell the program to retry.

b. Tell the program to retry (with the same tape).

c. Tell the program to try to write the header on the next physical tape record. This is a last resort and should be used only if there are no more tapes or the ones you have cannot be shuffled so that the first one is good.

After the header record is written successfully, you can start data acquisition by turning on the clock switch. If the clock is already on, data acquisition will begin immediately. Recovery of tape errors during data acquisition is not possible; however, the number of errors detected by the program can be monitored (data channel #59). If this channel increases regularly or gets above 10 or so, you have a serious tape problem and may as well stop and determine the cause. If you hit an extra return after this command, the program will execute command #5.

COMMAND 4. STOP A/D

Disables data acquisition. If tape output is in progress, the program writes an EOF on the tape and rewinds and ejects both tape cartridges.

The program does not record the last tape buffer, so you should wait a few seconds after the last event you want to record before you execute this command.

COMMAND 5. DISPLAY DATA

The program displays the most recent values in the data channels you have selected for display using command #7. The program also shows the header, the elapsed time in minutes and seconds, the number of tape records remaining until a track switch, the time of day taken from the date/time card, the current tape track number, the Raydist red lane count (left display), and the Raydist green lane count (right display).

Hit return to go from display mode to the command list.

COMMAND 6. SET UP CHANNELS TO A/D

Allows you to add a channel to the list of channels to be sampled or to restart the list with the channel entered. As each channel is selected, you enter the sample period in clock counts, where a clock count is 50 milliseconds (1/20 sec). The recommended responses are: 1, 2, 4, 5, 10, 20, and 40 which correspond to sample rates of: 20, 10, 5, 4, 2, 1, and .5 samples per second, respectively. Any channel between 0 and 63 can be selected. The standard channel assignments are given in Appendix B. Enter a channel number of 99 to exit this command.

COMMAND 7. SET UP CHANNEL DISPLAY

Allows you to add a channel to the list of channels to display or to restart the list with the channel entered. Enter a channel number of 99 to exit this command. This list may contain up to 20 channels. This command is convenient for finding out what the current display selections are, as follows:

a. Execute the command

b. Hit return (to add channels)

c. Observe current list

d. Hit return (to exit command)

COMMAND 8. CALIBRATE

Sets up the constants (slopes and normals) of the linear function for each data channel which is used to calculate engineering units from analog-to-digital converter counts. Three means are provided: standard, field, and normal-only calibration. Remember that any new calibration constants must be determined before data acquisition is started so that the new values will be recorded in the header.

STANDARD CALIBRATION:

Enter the slope and normals through the keyboard. The values are taken from the most recent calibration sheet (obtained from the computer center by activating program HIMS2CAL). A sample calibration sheet is included at Appendix D.

FIELD CALIBRATION:

The channel to be calibrated is driven to two points for which the measurement is known in engineering units. At each point you should sample the channel until you are satisfied that the value is constant. (The value displayed uses the "old" slopes and normals and may not be near the value to be set.) Then you enter the desired value in engineering units. When both points have been set, the old and new slopes and normals are displayed and you are asked to verify that the new slopes should be used.

NORMAL-ONLY CALIBRATION:

Same as the field calibration except that only one data point is sampled. This point will affect only the "normal" or zero offset value. Use this for correction of barometric altitude to make the displayed value agree with the pilot's indication since changes in the altimeter setting will cause the computed and the pilot's indicated values to differ.

NOTE: You must execute command #2 (start A/D only) before the calibrate command if you are going to do a field or normal-only calibration.

COMMAND 9. SAVE PROGRAM

This command provides a means for saving the program and the current values of all program parameters. Actually, the entire memory from location 500 through the top of memory is saved. A new tape (which is not "safe") should be inserted in the left drive. Retries are attempted in case of tape errors.

COMMAND 10. PRETENSION TAPE

This command spaces the tape in the left drive forward until end-of-tape is detected, then does a high-speed rewind. The tape drive manufacturer claims that older tapes can be read or written more reliably if this operation is performed just before the tape is used.

COMMAND 11. (SET ONBOARD CLOCK)

This unadvertised command is used to set the date and time on the date/time card. This command should be needed only if the battery on the date/time card becomes discharged. This battery is charged whenever the computer power is on and has an expected life of 3 months between complete charges.

COMMAND 12. (LOAD BOOTSTRAP)

This unadvertised command sets up a bootstrap program beginning at memory location 400. (It saves you the trouble of entering the bootstrap through the keyboard.) Use this command if you suspect that something is wrong with the program you are using. However, if the bootstrap PROM is installed, use of this feature is not required.

COMMAND 13. (NO TERMINAL)

This unadvertised command inhibits further input from the keyboard and further output to the screen. This would be the last command used on the ground to initialize a system which would run unattended during flight.

COMMAND 14. (PLAYBACK)

This unadvertised command is used when the program is run on the laboratory-based development system to read data from tape and transmit it to the SEL-85 hybrid computer for a verification printout. This option is no longer needed due to development of PDP-11 based data reduction software.

COMMAND 15. (LAB DEVELOPMENT SYS)

This unadvertised command is used to inform the program that data acquisition hardware is not present. This command enables you to run the HIMS-II program on a laboratory-based PDP-11/03 system for training or debugging purposes.

Appendix I

INSTALLATION PROCEDURE

After securing the HIMS-II rack and Raydist receiver (if used) to the aircraft, perform the following:

1. Insure that both HIMS-II power switches are off and make the following electrical connections:

a. Attach ground straps from the HIMS-II rack, the Raydist chassis, and the 60 Hz inverter to the lug behind the copilot's seat.

b. Connect the HIMS-II power (+28V DC and 115V AC) cables to the aircraft console connectors. Connect the cable from the HIMS-II "A" connector to the console connections. If the calibration box is used, route the "A" connector cable to the calibration box (instead of the console) and connect the power, "C" and "D" cables from the box to the HIMS-II.

c. Run the Raydist signal cables to the HIMS-II. Attach the antenna coax cable to the Raydist receiver.

d. Insure that the +28V DC input and 115V AC, 60 Hz output connections are made at the inverter.

2. Proceed with the power-up and computer bootstrap instructions given in Appendix G.

Appendix J

HIMS-II CALIBRATION

The recommended procedures for calibration of various HIMS-II data channels are given below. In all cases, allow a warmup period of at least 15 minutes for the HIMS-II.

CH 0. Rotor RPM: The frequency-to-DC converter is adjusted in the shop to an output of 5.0 VDC for 110% RPM, which equals 77 Hz in the converter. Load the output to simulate the HIMS-II channel loading. Obtain slope and normal for this channel by using the field calibration (2-point) technique with rotor stopped and at the normal in-flight value (325 RPM). Measure the voltages directly with the HIMS-II or with a digital voltmeter (DVM) and use voltage substitution at a later time. Be sure the DVM readings are obtained with the HIMS-II connected to the converter output.

CH 1. Barometric Altitude: Determine the altitude transducer characteristics, using the pilot's indicator as the standard, by using a pitot-static tester. Connect the transducer and pilot's altimeter (disconnect all other indicators) to the vacuum side of the P-S tester. Set 29.92 in the altimeter to reference the calibration to pressure altitude. Exercise the units several times before calibration to reduce frictional errors. With the HIMS-II energizing the transducer and using the pilot's altimeter as the standard, record transducer output voltages for various altitudes within the operating range. (Currently the HIMS-II is set to record altitudes up to 2600 feet.) Record voltages for both the increasing and decreasing directions. Repeat several times to increase the confidence level of the data. Use a simple regression technique to fit the data to a best straight line. The slope and normal for the HIMS-II can then be obtained by combining the transducer slope/normal with the filter card slope/normal.

For example:

The best straight line for the transducer output (in volts) is

$$V_T = 0.0411 + 0.0004438 \times ALT\ (Ft)$$

The filter card output is

$$V_{out} = 0.224 + 3.955 \times V_{in}$$

Combining the two equations ($V_T = V_{in}$) gives

$$V_{out} = 0.3984 + 0.001755 \times ALT\ (Ft)$$

Since one volt equals 204.91 counts in the analog-to-digital converter, the HIMS-II slope (in engineering units/count) would be:

$$\frac{1.00\ v}{204.91\ CNT} \times \frac{1}{0.001755\ \frac{v}{FT}} = 2.7807$$

The normal (in engineering units) is the displayed value with zero volts into the A/D converter. This is the negative of the voltage normal expressed in EUs:

$$\frac{0.3984\ v}{0.00177\ \frac{v}{FT}} = 227.85\ FT$$

or -227.85 feet.

These values of slope and normal are inserted into the HIMS-II using the standard calibration procedure.

CH 2. Barometric Airspeed: The airspeed transducer is calibrated in a manner similar to the altitude unit. Connect it and the pilot's airspeed indicator to the pressure side of the pitot-static tester. After exercising both devices, use a DVM to measure the transducer output at various airspeeds, in both increasing and decreasing directions, using the pilot's indicator as the standard. Repeat measurements several times. Using a simple regression technique, fit the data to the best function describing the points. The currently used airspeed transducer actually measures impact pressure (Q_C), therefore its output appears as an exponential curve with respect to airspeed.

Two calculations are involved with the airspeed function, the first being the airspeed transducer voltage (CH 2) and the second, the actual airspeed value (CH 64). Calibration of channel 2 merely involves using a voltage substitution at two points within the transducer output range. Use the field cal technique. Channel 64 uses the output of channel 2 and constants derived from the regression procedure.

For example:

The best fit curve for the transducer output is

$$V_T = 0.25461 \times e^{0.01657 \times \text{AIRSPEED (KTS)}}$$

If channel 2 has a display based on the A-D output (in counts) of

$$V_{out} = 0.3268 + 0.0015 \times (\text{COUNTS})$$

then solving for airspeed in the first equation and inserting the effect of channel 2 gives

$$\text{AIRSPEED (KTS)} = \frac{\ln\left[(0.3268 + 0.0015 \times \text{COUNTS})/0.25461\right]}{0.01657}$$

This result is displayed as channel 64.

CH 3-7. Cyclic Fore-Aft, Cyclic Left-Right, Collective, Throttle, and Pedal Positions: These channels are all calibrated in a similar manner. Use the field calibration procedure on the HIMS-II to measure transducer output with the controls at their extreme travel positions. These two-point cals are normally equated with percent of control movement, as shown below:

CH 3	CYC F-A	Fwd = +100%; Aft = -100%
CH 4	CYC L-R	Left = -100%; Right = +100%
CH 5	COLL	Down = 0%; Up = +100%
CH 6	THROT	Closed = 0%; Open = +100%
CH 7	PEDAL	Left = -100%; Right = +100%

CH 8-11. LORAS Velocity airspeed, LORAS Longitudinal airspeed, LORAS Latitudinal airspeed, and Radar Altitude: These four functions have convenient test provisions built into the pilot's indicator systems which are used for calibration. For the three LORAS channels, the calibration (two-point field cal) must be done on the ground in calm wind conditions to obtain stable readings. Also, the LORAS unit should be warmed up as much as possible (10 minute maximum operation on the ground). For each channel, measure the "zero" and test positions with the HIMS-II, entering the reading on the indicator, and allowing the HIMS-II to calculate the slope and normal.

The radar altitude channel is calibrated in a similar manner, using the HIMS-II to measure "zero" and test position readings. Enter whatever the pilot's indicator reads at each point into the HIMS-II field cal routine.

CH 12-17. Sine Roll, Cosine Roll, Cosine Heading, Sine Heading, Cosine Pitch, and Sine Pitch: These six channels all are calibrated using the two-point field cal technique. Use a synchro simulator to generate signals which are converted in the HIMS-II to sine and cosine values representing the synchro angles. Use values of 0^0 and 90^0 at the simulator and equate these to 0 and 1 for sine channels, or 1 and 0 for cosine channels, during the cal procedure.

The actual heading, pitch and roll angles are displayed in channels 65, 66, and 67. These are calculated in the program and do not require calibration.

CH 18-20. Roll, Pitch, and Yaw Rates: Calibration for these channels is performed by using a voltage substitution based on the manufacturer's calibration sheet. Use a two-point field cal allowing the HIMS-II to calculate slopes and normals, inputting two voltage values near the extremes of the sensor output.

CH 21-23. X, Y, and Z Accelerations: Perform a ± 1g flip-over calibration for each channel. (Remove the accelerometers from the HIMS-II rack for this test.) The two-point field cal procedure will calculate the proper slope and normal. Use care in the flip-over process to reduce frictional errors. Repeat if necessary to obtain satisfactory results.

CH 24. Vertical Airspeed: Measure the "zero" output of the transducer as it is loaded by the HIMS-II circuitry. Use this value and the manufacturer's

published value of 2mv/fpm (or +4.00v @ +2000fpm) in a voltage substitution two-point field calibration. The HIMS-II program will determine the slopes and normal for the channel. The difference in time constants between the pilot's IVSI indicator and the vertical airspeed transducer makes in-flight calibration impractical.

CH 25. Slip: Calibration for this channel must be performed in flight. Using the two-point field cal procedure, measure the transducer outputs with the HIMS-II while the aircraft is flying in a one-ball left and one-ball right (as shown on the pilot's indicator) condition.

CH 26-63. User-defined Channels: Calibrate using end-to-end or voltage substitution two-point field cal techniques whenever the source output is known as being linear. Nonlinear outputs must be treated differently--requiring specialized software for each case.

NOTE: All slopes and normals derived from field calibrations should be recorded manually and/or recorded on tape after the calibration is performed.

Appendix K

TRADE NAME INFORMATION

Raydist (Teledyne Hastings-Raydist)
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DEC (Digital Equipment Corporation)
Maynard, MA 01754
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ADAC Corporation
70 Tower Office Park
Woburn, MA 01801
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Hazeltine
500 Commack Road
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(516) 462-5100

Digital Pathways, Incorporated
1260 L'Avenida
Mountain View, CA 94043
(415) 969-7600

Qantex
Division of North Atlantic Industries
60 Plant Avenue
Hauppauge, NY 11787
(516) 582-6060

Minnesota Mining & Manufacturing Company
3M Center
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Frederick, MD 21701 (5)

Redstone Scientific Information
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US Army Missile R&D Command
Redstone Arsenal, AL 35809 (1)

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US Army Aviation Engineering
Flight Activity
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Edwards AFB, CA 93523 (1)

US Army Combat Developments
Experimentation Command
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Fort Ord, CA 93941 (1)

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Harry Diamond Laboratories
Scientific & Technical Information
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2800 Powder Mill Road
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US Army Ordnance Center & School
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US Air Force Armament Development
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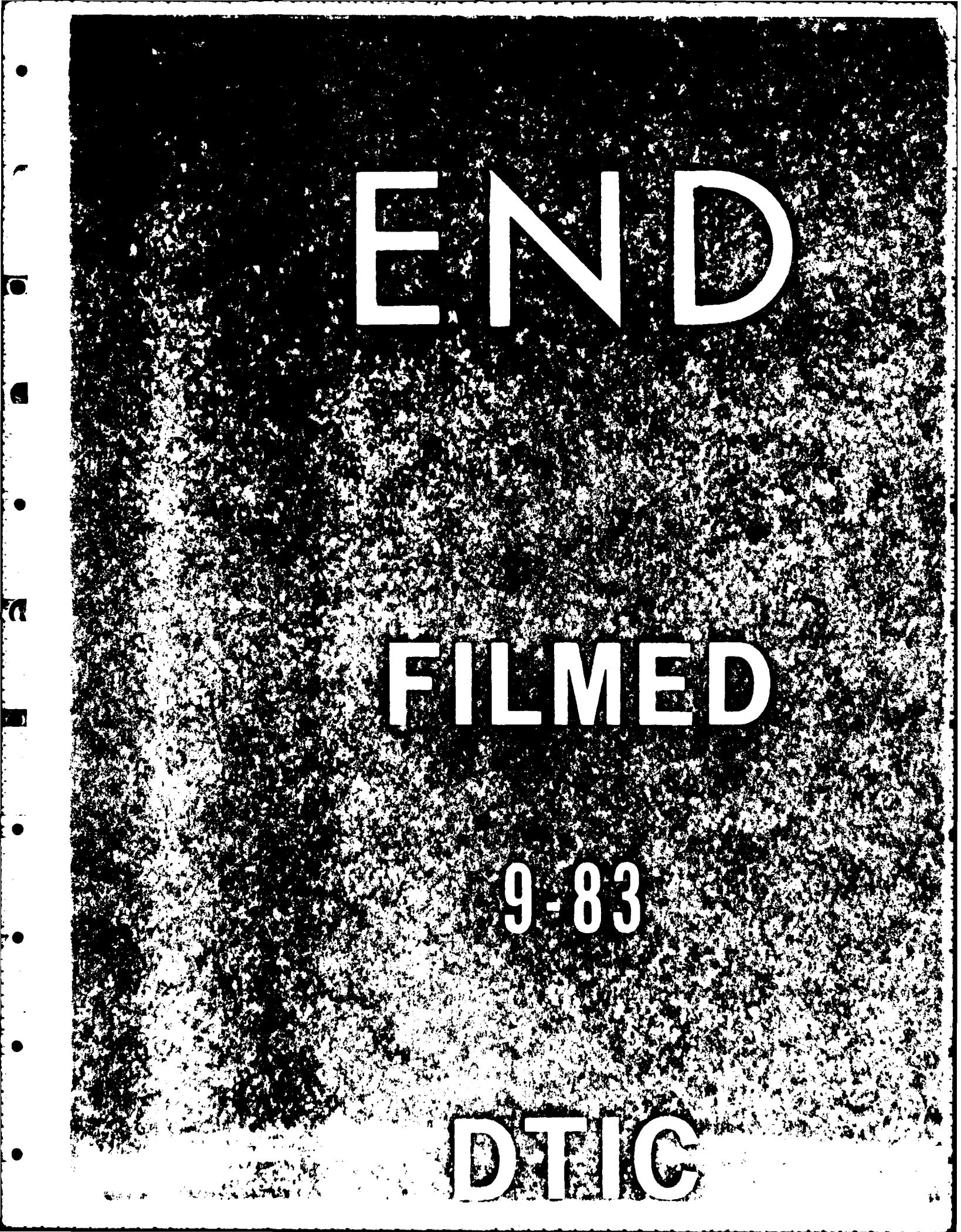
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